Nocturnal forest birds and arboreal marsupials of the southwestern slopes, New South Wales

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ABSTRACT

A regional survey of 253 forest sites on the southwestern slopes and adjacent highlands of New South Wales recorded a total of 530 animals from five species of nocturnal forest birds and nine species of arboreal marsupials. One additional species, the Squirrel Glider *Petaurus norfolcensis*, was trapped during supplementary searches. Elevation (climate) and forest type were the major factors accounting for the distribution of this fauna. Minor environmental gradients included geology, the density of hollow-bearing trees, topography, logging intensity and fire. The patterns of landuse in the region contributed to interactions between elevation, forest type and management history (logging, fire and grazing) which restricted inferences about the habitat requirements of animals.

Forest types occurring at either end of the elevational (wet-dry) gradient (Alpine Ash and Box-Stringybark) were poorer in species than forests occurring at intermediate elevations (Alpine Gums, Wet Peppermint and Dry Peppermint). The Wet Peppermint forest type, which was the richest in species of nocturnal animals, has been deliberately selected in the past for conversion to pine plantations. The fauna of the region was generally more sparse and patchy compared to four other regions (northeastern and southeastern New South Wales, and northeastern and Central Highlands of Victoria) where similar studies have been undertaken. Numbers of large forest owls and the Greater Glider *Petauroides volans* were recorded less commonly than expected and may have declined in the region. The Common Brushtail Possum *Trichosurus vulpecula* was particularly abundant. This species and the Common Ringtail Possum *Pseudocheirus peregrinus* appeared to maintain their numbers in small (<2 000 ha), isolated forest fragments.

INTRODUCTION

The original vegetation of the southwestern slopes region of New South Wales has become highly fragmented as a result of extensive forest clearing for agriculture and the establishment of pine plantations. Native forest is now confined generally to areas of more rugged topography and lower nutrient soils compared to the surrounding landscape. A number of small, isolated State Forests contribute greatly to protection of the existing native forest and play an important role in conserving the native fauna of the region. The only published study of fauna in the region was concerned with the distribution of reptiles and amphibians (Caughley and Gall 1985). That study found species richness of the herpetofauna to be determined primarily by forest area.

The eastern edge of the southwestern slopes merges with the Southern Tablelands and alpine region where Kosciuszko National Park provides an extensive area of reserved native forest. A transitional zone ranging in elevation from about 400 to 1 400 m above sea level lies between the two regions and is occupied by three large State Forests, Bago, Maragle and Buccleuch, each of which adjoins Kosciuszko National Park. No fauna surveys covering these three State Forests have been published, although several notable studies have been conducted on single species (e.g., Tyndale-Biscoe and Smith 1969a; McIlroy 1973; Jaremovic 1984; Osborne 1990). Tyndale-Biscoe and Smith (1969b) demonstrated that one species, the Greater Glider *Petauroides volans*, had a poor ability to establish itself in nearby suitable habitat following displacement caused by clearfelling of native forests to plant pine *Pinus radiata*.

The Tumbarumba Hardwoods Region is managed by State Forests of New South Wales through its district offices at Tumbarumba and Tumut. The Management Area includes 19 State Forests distributed between the western and northern edges of Kosciuszko National Park westwards almost to Wagga Wagga and Albury. Timber harvesting ranges from low intensity in the western forests in the region to intensive over a long period in the Alpine Ash *Eucalyptus delegatensis* forests of the higher elevation forests in the east.

The aim of the present study was to document the regional distribution of nocturnal birds and arboreal mammals in relation to environmental variables and management history. Particular efforts were made to assess the distribution and habitat relationships of this fauna in the largest, contiguous forest area, Bago and Maragle State Forests, to provide baseline data for

future work on the ecological sustainability of forest management practices. The broad-scale surveys were intended to provide a context for the interpretation of data collected from Bago-Maragle. The conservation significance of the region is discussed. Companion studies in the region include those by Law *et al.* (1998) on bats, Lemckert (1998) on herpetofauna, and Stanton and Anderson (1998) on terrestrial mammals.

METHODS

Study area

The Tumbarumba Hardwoods Region covers the western edge of the Southern Tablelands and the more rugged areas situated in the eastern part of the south-western slopes region of New South Wales between 35 and 36 degrees south latitude and 147 and 149 degrees east longitude (Fig. 1). The major drainage systems flow to the west via the Murray and Murrumbidgee Rivers. A total of 19 state forests represent the most substantial areas of native forest remaining in the region (Fig. 2). Four of these, Bago, Maragle, Buccleuch and Woomargama State Forests, are about 20 000 ha or larger in size, while the remainder are less than 4 000 ha (Table 1). In general, the areas of native forest in the region occupy the hilly locations that were unattractive for conversion to agricultural land uses because of steeper slopes and relatively low soil fertility, and the greater frequency of snow falls or heavy frosts (Table 1). Many of the most fertile, mid elevation and lower gradient areas of state forest in the region, particularly those characterized by Manna Gum *E. viminalis*, Mountain Gum *E. dalrympleana* and Robertson's Peppermint *E. robertsonii*, have been converted to *Pinus radiata* plantations (Anon. 1984). Exotic plantation establishment in the region commenced in 1921. Planting continued after World War II and a large increase occurred during the 1960s and 1970s (Anon. 1984). Broadscale conversion of native forest to pine plantations continued until about 1990, but clearing still occurs on private land.

Elevations within State Forests range from approximately 300 metres to 1 450 metres. Rainfall is strongly associated with elevation, so while there is a general trend for the forest to become drier to the west, several western state forests have moderately high peaks which generate considerable rainfall and subsequently support relatively wet forest types. The best example of this is south west Woomargama which has peaks to 900 metres and is heavily forested with smooth-barked and peppermint eucalypts. Also, the 650 metre peak of Benambra State Forest appears to generate sufficient rainfall to support wetter forests than lower elevation forests to the east.

Hardwood logging and management in the region has been concentrated in the high value Alpine Ash stands of Bago, Maragle and Buccleuch State Forests. Forest types dominated by Alpine Ash occupy approximately 36% of Bago State Forest and 12%

Table 1. Distribution of survey sites by State Forest on the southwestern slopes of New South Wales. The area of each State Forest or land unit is indicated together with the altitudinal distribution of sampling sites.

Land Unit	Total forest area (ha)	Native timber area (ha)	Sites	Mean ha/site	Sampled elevation Maximum	Minimum	Mean
Bago State Forest	50 570	37 000	88	420	1 300	400	1 079
Woomargama State Forest	32 450	32 000	27	1 185	1 330	570	1 010
Buccleuch State Forest	69 050	26 000	34	765	1 240	810	1 070
Maragle State Forest	22 270	19 800	38	521	810	300	585
Carabost State Forest	19 420	3 700	8	463	700	450	578
Tumut State Forest	3 770	3 400	5	680	760	540	654
Mundaroo State Forest	6 070	3 000	7	429	470	360	407
Murraguldrie State Forest	4 490	3 000	5	600	730	330	516
Bungongo State Forest	3 770	2 700	5	540	640	450	540
Livingstone State Forest	2 190	2 180	6	363	770	550	698
Ournie State Forest	2 180	2 170	3	723	730	560	660
Clarkes Hill State Forest	2 100	2 100	3	700	890	690	780
Mannus State Forest	3 320	2 000	4	500	710	600	653
Minjary State Forest	1 400	1 400	3	467	630	500	563
Benambra State Forest	1 400	1 400	3	467	640	310	423
Green Hills State Forest	25 590	1 000	2	500	400	380	387
Ellerslie State Forest	900	900	3	300	400	400	400
Pulletop State Forest	760	760	3	253	860	730	795
Tumblong State Forest	690	690	0	*NA*	*NA*	*NA*	*NA*
Mt Garland VCL (Mannus)	*NA*	2 000	1	*NA*	630	630	630
Kosciuszko National Park	*NA*	*NA*	5	*NA*	1 440	720	1 080
State Forest total	252 390	145 200	247	588	1 330	300	889
All sites total			253		1 440	300	892

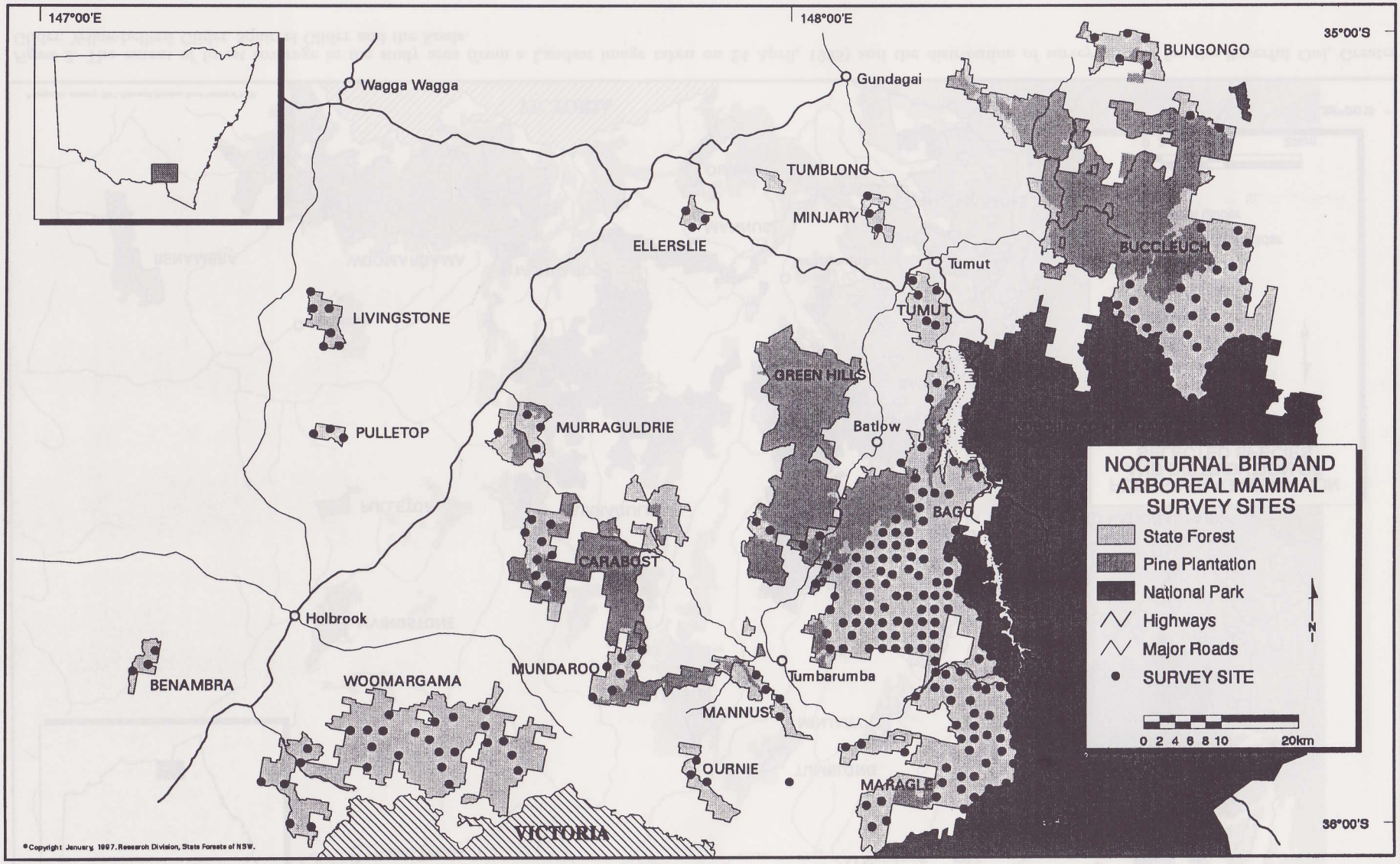


Figure 1. Distribution of the 253 survey sites by state forest and national park in the Tumbarumba Hardwoods Region.

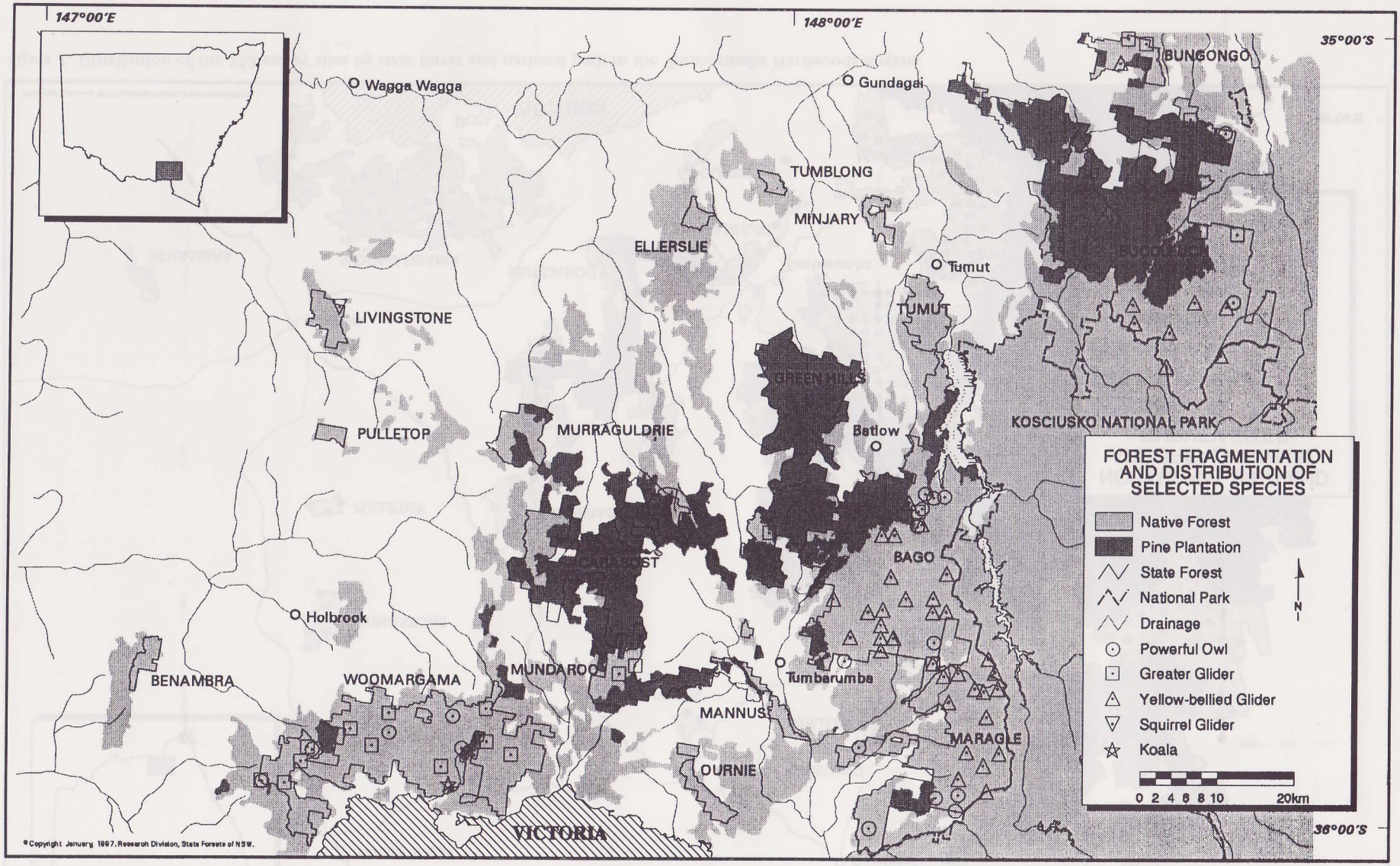


Figure 2. The extent of forest coverage in the study area (from a Landsat image taken on 24 April, 1995) and the distribution of survey records for the Powerful Owl, Greater Glider, Yellow-bellied Glider, Squirrel Glider and the Koala.

of Maragle State Forest (Anon. 1986), and a smaller proportion of Buccleuch State Forest. Alpine Ash forests have been heavily logged since the turn of the century and unmerchantable trees and less desirable species have been culled since at least 1917 (Anon 1986). Post-logging burning has been used to improve tree regeneration. Logging practices were particularly intensive during the period 1954 to 1969 (Anon. 1986) resulting in many areas of even aged re-growth with few if any old trees containing hollows. Alpine Ash is moderately fast growing but hollows appear to form very slowly in this species. Trees in excess of one metre in diameter are uncommon but even such large old trees have few hollows suitable as shelter for arboreal mammals.

The Mountain Gum and Peppermint forest types occupy about 30% of Bago and Maragle State Forests (and a similar proportion of Buccleuch State Forest) and constitute the main non-Ash hardwood component of commercial operations in the region (Anon. 1986). Harvesting of these stands in Bago did not commence until the 1960s, while those in Maragle, including the Ash stands, remained unlogged until 1968. Since that time, most of the economically accessible stands in Maragle State Forest have been logged. Gums such as Mountain Gum and Manna Gum appear to form useful hollows for animals at an earlier age than Alpine Ash. Forest types dominated by Eurabbie *E. bicostata* or Snow Gum *E. pauciflora* and Mountain Gum also have commercial importance. However, most of the lowland or western forest types in the region are of low commercial value and are logged only selectively for fence posts or firewood, if logged at all.

Stratification

Numbers of nocturnal birds and mammals were estimated at 253 sites distributed throughout the region. Given the dual objectives of the study, which were to establish the baseline for future detailed studies in Bago-Maragle and to sample the range of forested environments in the region, a combination of approaches was required. A 1.7 km grid, derived from a randomly located point of origin, was the basis for sampling in Bago and Maragle State Forests (Fig. 1). This approach provided an acceptable separation between adjacent survey sites thus minimizing problems of double counting wide-ranging fauna. Also, the good road network enabled access by vehicle and foot to most of these points so that it was possible to sample the range of environments present in the study area. Access was more difficult in all other State Forests so it was inefficient to use grid-based sampling in these areas. Instead, sampling sites were located to include a range of forest types and topography. For example, in a small forest such as Ellerslie State Forest (900 ha), the three sites were located on a ridge, in a creek line and on a mid-slope. Each site also sampled one of the predominant forest types occurring in Ellerslie. Outside Bago-Maragle most sites were placed near minor roads or tracks.

A total of 126 sites (49.8%) were located in Bago-Maragle, 121 sites (47.8%) were located in 17 additional state forests, 5 sites (2.0%) were located in Kosciuszko National Park, and one site (0.4%) was located in vacant Crown land near Mount Garland (Table 1). Each site was surveyed once in autumn 1995 (27 March–18 May).

Targetted trapping for the Squirrel Glider *Petaurus norfolcensis* between 8–30 May, 1995 sampled Bago, Benambra, Livingstone, Mannus, Murraguldrie, Pulletop and Woomargama State Forests. Traplines were set in areas below 500 m elevation among box, ironbark and stringybark ("Western"; see below) forest types on wide flat gullies.

Survey methods

The numbers of all species encountered were estimated on variable-radius plots centred on each site. The survey procedure was to spend 15 minutes listening for unelicited vocalizations and non-vocal cues indicating the presence of animals, followed by 15 minutes (three species for five minutes each) of broadcasting pre-recorded owl vocalizations and waiting for a response. In all areas where "wet" forest types (Alpine Ash, Alpine Gums and Gully Gum/Peppermint forests; n = 173) were present the calls broadcast were, in order, Sooty Owl *Tyto tenebricosa*, Powerful Owl *Ninox strenua* and Masked Owl *T. novaehollandiae*. However, the species sequence was changed to broadcast Powerful Owl, Masked Owl and Barking Owl *N. connivens* for surveys in "dry" forest types (Dry Peppermint and "Western" forests; n = 80) as habitat suitable for the Sooty Owl was not present in the western forests of the Tumbarumba Hardwoods Region. In addition, two calls of a male Koala *Phascolarctos cinereus* were broadcast at the end of the owl call playback sequence. A megaphone (Toa ER-66), with power output rated at 10 W, was used to broadcast owl vocalizations in several directions. These call playbacks were effective (audible to the human ear) for a distance of at least 1 km. Finally, 10 minutes were spent searching an

area of approximately one hectare with a 100 W spotlight for any nocturnal birds or mammals present at the site. An additional 5 minutes were spent at the end of the spotlighting period to record any observations and to extend the listening period for any late responses by owls. Thus each site was sampled "actively" for 25 minutes and "passively" for 20 minutes.

Ninety-six percent of counts were shared between two observers, each of whom surveyed five sites per night beginning shortly after dusk. The survey procedure was designed to be effective in detecting the presence of large forest owls, however, the combination of methods used is effective for detecting a wide range of nocturnal fauna (e.g., Kavanagh 1984; Kavanagh and Peake 1993a).

Trapping for Squirrel Gliders was conducted on 11 traplines in seven State Forests (see above) for a total of 440 trap nights. Type B (large) Elliott traps were mounted on tree brackets approximately 2.5 m above the ground. The bait was a mixture of peanut butter, rolled oats and honey, and honey water was sprayed on each tree several metres above the trap. Traps were set 20 m apart in lines of 10 traps and checked daily over four days.

Environmental variables

A standard set of environmental variables was measured at each site or was obtained from topographic and vegetation maps (Table 2). Sites were located on the ground (Australian Map Grid co-ordinates and elevation) using GPS units and 1:25 000 topographic maps. The variables of position in landscape, topography and aspect were determined on site (see categories in Table 2). Position in landscape refers to the topographic position of each site, i.e., ridge, mid-slope or gully. Topography is an approximate measure of roughness or gradient on a scale of flat, undulating, hilly and mountainous. Aspect is a measure of exposure to mid-afternoon sun, thus a slope facing north-west would have the highest exposure, a flat area or slope facing south-west or north-east would have a medium exposure and a slope facing south-east would have the least exposure.

Geology was determined from 1:250 000 geology maps, primarily the Wagga Wagga Metallogenic/Geologic Sheet (Degeling 1977). A corrected map for Bago-Maragle was available which modified the geological typing for some sites. Sites within 500 metres of a geological boundary were classified as having both types of geology. Sites were located over 12 geological types but were broadly grouped for analysis into granitic, sedimentary/metasedimentary, basaltic and extruded igneous (other acidic volcanic) types.

Four forest qualities were assessed. Predominant forest type was determined from

Table 2. Summary of environmental variables measured at survey sites. Data represent the percentage of sites (n = 253) scored in each category for environmental variables.

Habitat variable	Categories	% of sample	Habitat variable	Categories	% of sample
Elevation (m above sea level)	300– 649	25.3	Forest groups	Alpine Ash	17.4
	650– 899	20.2		Alpine Gums	18.2
	900–1 149	28.1		Wet Peppermints	32.8
	1 150–1 440	26.5		Dry Peppermints	11.5
				Western Types	20.2
Position in landscape	Gully	25.3			
	Midslope	49.4	Habitat Trees per Hectare	0–1	45.5
	Ridge	25.3		2–3	37.2
				4+	17.4
Topography	Flat/Undulating	35.6			
	Hilly	44.3	Understorey height (m)	0–1.5	57.3
	Mountainous	20.2		1.5–3.5	34.8
				3.5–5	7.9
Aspect	Exposed	22.1			
	Intermediate	51.4	Understorey density	Sparse	24.1
	Sheltered	26.5		Medium	36.8
				Dense	39.1
Land tenure	State Forest	97.2			
	National Park	2.0	Fire	No Evidence	90.9
	Vacant Crown Land	0.8		Burnt (<5 years)	9.1
Geology	Granite	57.7	Logging	No Evidence	48.2
	Sedimentary	19.6		Selective	30.8
	Others	22.7		Heavy	20.9

State Forests of New South Wales maps of forest types at 1:25 000 scale and checked at the time of the survey. Many of the non-commercial forest areas were not covered by forest type maps so these were assessed on site. Forest structure was assessed by counts of trees per ha containing large hollows for possums and gliders (habitat trees), and visual estimates were made of understorey density and understorey height (m).

Logging history maps were available for only some areas. Therefore, the extent of logging was assessed visually on site by observations of the forest structure, including numbers of stumps and old hollow trees, the density of eucalypt regrowth, and the presence of logging tracks. For analysis, logging history was grouped into one of three categories: unlogged, selectively logged and heavily logged (either recently or in the past). Fire history was assessed by observations of charring on tree trunks or stems, charcoal on the ground and the density of understorey regeneration. For analysis, fire history was grouped into two categories: no evidence of fire and recently burnt (probably within the previous five years). Details of weather and moon phase were recorded.

Analysis

The relations between the 10 most abundant animal species and a set of 18 environmental variables measured at each site were summarized using canonical correspondence analysis (CCA) and presented graphically as a biplot (Gabriel 1981; ter Braak 1986, 1987; see also Kavanagh *et al.* 1995b). The environmental variables consisted of five forest groups, four geological groups, four landscape features, three forest structures and two forest impacts. Counts of animals were used in the analysis (rather than presence/absence data). A dummy species variable was constructed to represent sites where no species were recorded. Prior to analysis, the joint distribution of species variables was examined by means of a normal probability Q-Q plot to reveal the occurrence of possible unusual sample points (outliers) or non-linearity in the sample (see Kavanagh *et al.* 1995b). Several transformations were tried empirically. A log transformation was found to have the strongest linearising effect on the joint distribution of species.

Contingency chi-square analysis and Fishers Exact Test (Zar 1984; SAS 1986) using presence-absence data for species were used to determine the levels of association between species occurrence and several variables shown to be important in the biplot, namely elevation, broad forest type, logging history and the numbers of retained hollow-bearing trees. These analyses were performed across either the full 253 sites or across subsets of 129 sites (consisting of all sites in two of the three commercially logged forest type groups) and 80 sites (consisting of all sites occurring in the two dry forest type groups). For some species, insufficient counts in the partitioned datasets precluded valid test results.

Broad forest types were classified by amalgamating standard State Forests of New South Wales forest types (see Anon. 1989) as follows. Alpine Ash consisted of forest types 147 and 148 (mainly *E. delegatensis*); Alpine Gums consisted of forest types 137, 138, 140, 141 and 143 (mainly *E. dalrympleana, E. pauciflora, E. stellulata* and *E. camphora*); Wet Peppermint consisted of forest types 131, 159, 160, 164 and 164/177 (mainly *E. robertsonii, E. dalrympleana, E. viminalis* and *E. bicostata*); Dry Peppermint consisted of forest types 111, 111/124 and 131/124 (mainly *E. dives* and *E. macrorhyncha*); and Western Types consisted of forest types 124, 125, 117 and 109 (mainly *E. macrorhyncha, E. bridgesiana, E. polyanthemos* and *E. mannifera*). The Alpine Ash, Alpine Gums, and Wet Peppermint were the main commercial forest types.

For analyses by elevation, sites were grouped into four categories: less than 650 m, 650–899 m, 900–1 149 m and greater than 1150 m above sea level. Habitat tree categories were formed by grouping 0 and 1, 2 and 3, and 4 or more retained hollow-bearing trees per ha and were analysed only for the 129 sites in two of the three commercial forest type groups.

RESULTS

Five species of nocturnal birds and nine species of arboreal marsupials were recorded during the survey counts. Less commonly recorded species included the Koala (one individual in Woomargama State Forest), the Eastern Pygmy Possum *Cercartetus nanus* (one individual in Green Hills State Forest), the White-throated Nightjar *Eurostopodus mystacalis* (one individual in Buccleuch State Forest) and the Feathertail Glider *Acrobates pygmaeus* (two individuals in Tumut State Forest). One Squirrel Glider (a female) was trapped on a Red Ironbark *E. sideroxylon* in Livingstone State Forest during the targetted survey for this species. Incidental records for the Spotted Nightjar *E. argus* were made in Livingstone State Forest, and also at a number of additional locations for the White-throated Nightjar. Records for three

additional species (Barking Owl, Masked Owl and Barn Owl *Tyto alba*) were obtained from other sources (Table 3). The occurrences of all species by State Forest or National Park in the region are presented in Table 3.

The distribution of five species in the region, four of which are listed as vulnerable species by the *New South Wales Threatened Species Conservation Act 1995,* is presented in Figure 2. The Yellow-bellied Glider *Petaurus australis* was recorded only in Bago, Maragle, Buccleuch and Bungongo State Forests. The Greater Glider and the Powerful Owl were frequently recorded in Woomargama State Forest. The Greater Glider was apparently rare or absent throughout large areas of Bago, Maragle and Buccleuch State Forests.

Environmental gradients and species assemblages

Elevation was the major environmental gradient accounting for the distribution of species in the Tumbarumba Hardwoods Region (Fig. 3). High elevation sites were correlated with the presence of Alpine Ash and Alpine Gums forest types, basalt and granite geologies, and logging. Low elevation sites were correlated with the presence of Dry Peppermint and Western forest types, sedimentary geology, fire, and steeper topography. A second, independent, gradient was related to the numbers of retained hollow-bearing trees per ha, the presence of the Wet Peppermint forest type and, more weakly, characteristics of the forest understorey (Fig. 3).

The biplot shown in Figure 3 provides a succinct summary of the multivariate relationships between species and the environmental variables measured at each site. Further details of the relationships between species and the major environmental variables of elevation, broad forest type and geology, are represented graphically in Figure 4. This figure illustrates that most species, forest types and geologies were represented across a wide range of elevations in the region.

The Yellow-bellied Glider and the Mountain Brushtail Possum *Trichosurus caninus* were strongly associated with high elevation and high soil fertility (basalt or granite, compared to sedimentary geology) sites which were

Table 3. Occurrences of nocturnal forest birds and arboreal marsupials by State Forest and National Park on the south-western slopes. Records made during the survey are indicated by either X or x (see footnote).

Species	Bago	Maragle	Buccleuch	Woomargama	Carabost	Mundaroo	Livingstone	Bungongo	Kosciuszko NP	Manus	Murraguldrie	Tumut	Benambra	Clarkes Hill	Ellerslie	Minjary	Ournie	Pulletop	Green Hills	Tumbalong
Powerful Owl	X	X	X	X			D							X						
Barking Owl								N												
Southern Boobook	X	X	X	XNf		X	n	XBN	X	X	N	Bn	Xn		X	X	X	X		
Masked Owl								*1996												
Barn Owl									C			m	n							m
Australian Owlet-nightjar	X	X	X	X		X		XN		X		X	X	X	X	X		X		
White-throated Nightjar	x			X	x		xN								x					
Spotted Nightjar							xN													
Tawny Frogmouth	Xm	X	X	XNf	X	X	N	BN	m	X		XBN	X	X			X	X		
Mountain Brushtail Possum	X	X	XM			X			K										X	
Common Brushtail Possum	Xn	X	Xm	XNf	X	Xh	XBN	XN	XCK	X	BN	BN	XBn	X	XB	X		B		
Common Ringtail Possum	X	X	Xm	XNf	b	Xh	XBN	X	CK	X	BN	Bnm	XBn		XB	X	X	X		
Greater Glider	Xn		XM	XNf		Xh		XN	CK										X	
Yellow-bellied Glider	X	X	XC					X												
Squirrel Glider							x	N												
Sugar Glider	X	X	XmC	XN	X	X		BN	K	X	B	XN		X			X		m	
Feathertail Glider	N		xmC	N					M			X	n						m	
Eastern Pigmy Possum									MK				n						X	
Koala				XN					K											
No. sites in area (X)	88	38	34	27	8	7	6	5	5	5	5	5	3	3	3	3	3	3	2	0

Lower case indicates records made near but outside State Forest boundaries (except X).
X = This Study (n = 253 sites), x = target survey or opportunistic record
B = Darren Boss (pers. comm.)
N = National Parks and Wildlife Service (B. Gall, pers. comm.)
M = Australian Museum Specimen
C = CSIRO database
K = Kosciuszko Study (Anon. 1946)
D = Historical Record (Debus and Chafer 1994)
f = Ferndale Study (Moore *et al.* 1992)
h = Horse Creek and Coppabella Study (Klomp and Marshall 1995)
* = Unpublished records

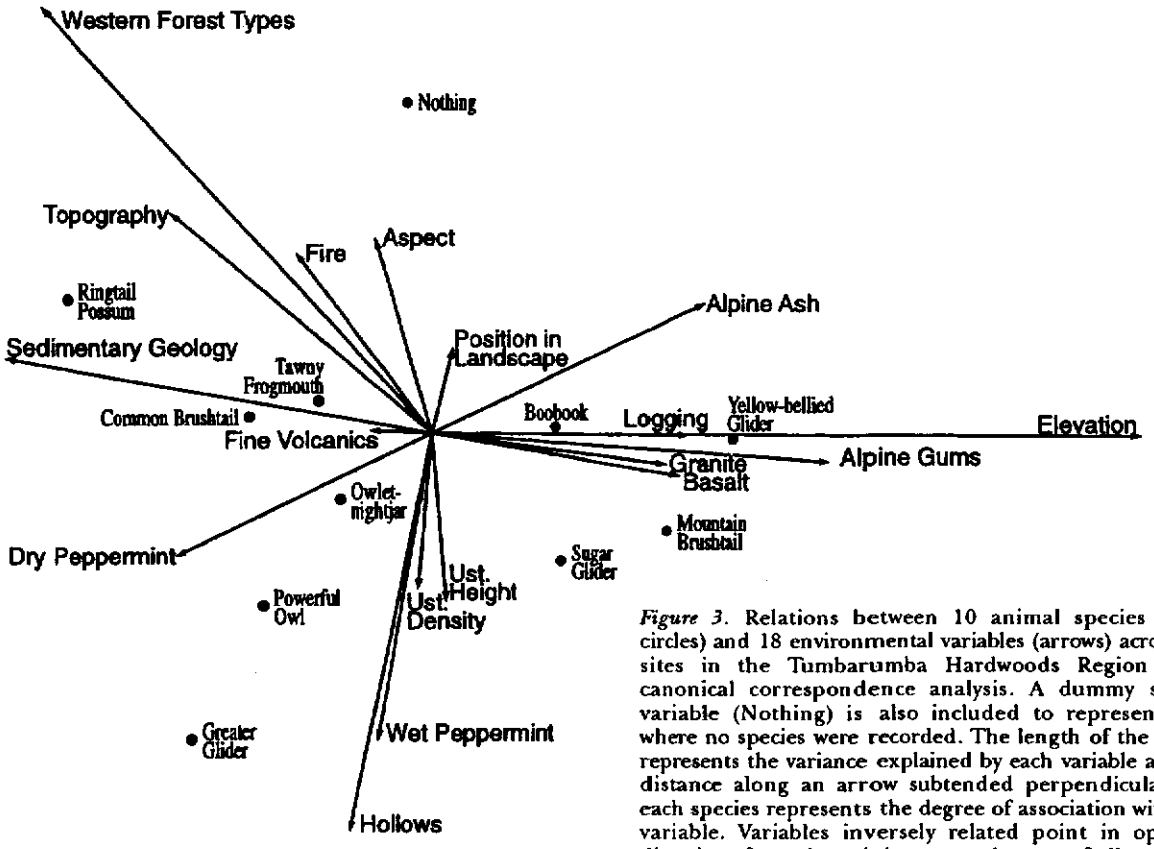


Figure 3. Relations between 10 animal species (filled circles) and 18 environmental variables (arrows) across 253 sites in the Tumbarumba Hardwoods Region using canonical correspondence analysis. A dummy species variable (Nothing) is also included to represent sites where no species were recorded. The length of the arrows represents the variance explained by each variable and the distance along an arrow subtended perpendicularly by each species represents the degree of association with that variable. Variables inversely related point in opposite directions from the origin or grand mean of all variables.

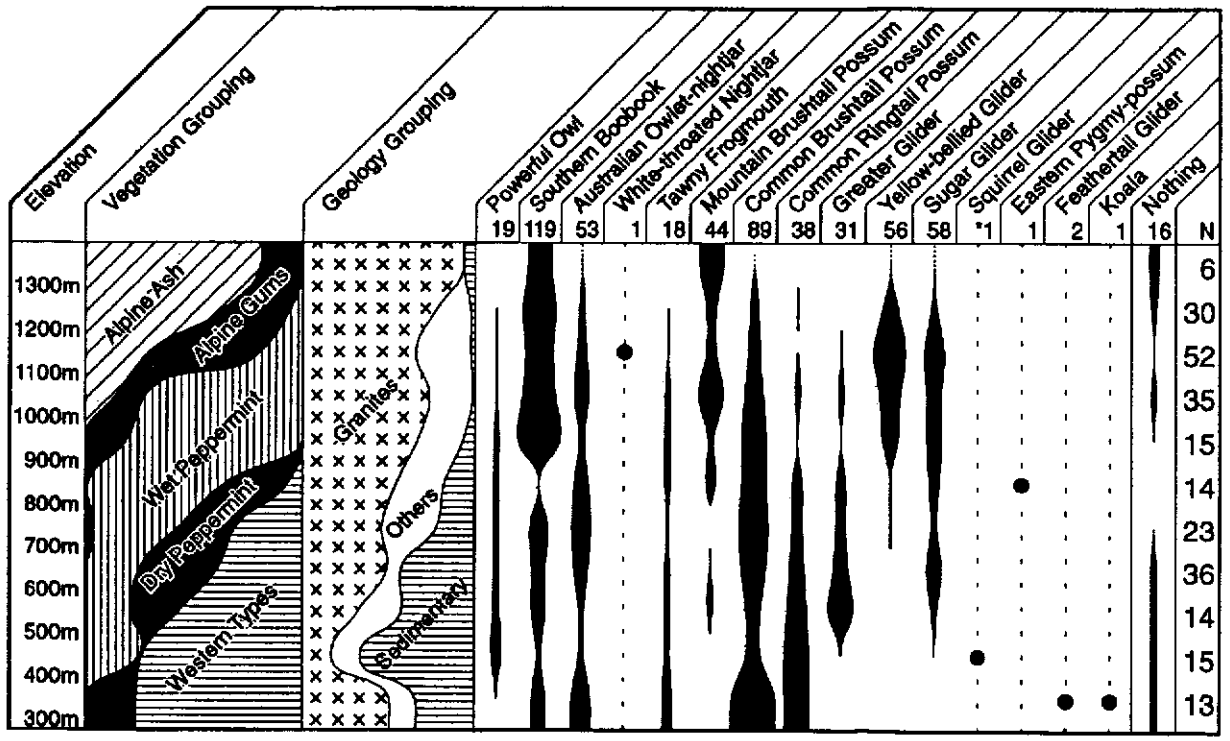


Figure 4. Relative abundance of species and distribution of broad forest types and geology by elevation in the study area. Data were partitioned into 100 m elevation classes. N represents the number of sites surveyed in each elevation class. Sample sizes are provided for each species.

usually logged at this elevation in the region (Fig. 3, Fig. 4). The Southern Boobook *Ninox novaeseelandiae* and the Sugar Glider *P. breviceps* showed similar but weaker associations. The Greater Glider, Common Ringtail Possum *Pseudocheirus peregrinus*, Powerful Owl and the Common Brushtail Possum *T. vulpecula* were strongly associated with low elevation sites, but occurred across a broader range of environments (Fig. 3, Fig. 4). The Greater Glider, in particular, and also the Powerful Owl and Australian Owlet-nightjar *Aegotheles cristatus*, were more likely to be recorded among the two Peppermint forest types and, in the case of the Greater Glider, where hollow-bearing (habitat) trees were more abundant (Fig. 3). The Common Ringtail Possum, in particular, and also the Common Brushtail Possum and Tawny Frogmouth *Podargus strigoides*, were more likely to be recorded among the Western and Dry Peppermint forests on sedimentary geology and steeper slopes that, typically, were not heavily logged although they may have been burnt (Fig. 3, Fig. 4). Sites where no species were recorded were more likely to occur among the Western or Alpine Ash forest types where few or no habitat trees were present (Fig. 3, Fig. 4).

Pattern in relation to elevation

Most species showed particular clumping in their patterns of distribution in relation to elevation throughout the native forests of the region (Table 4). Species more likely to occur at elevations above 900 m included Southern Boobook, Mountain Brushtail Possum and the Yellow-bellied Glider. Species more likely to occur at elevations less than 900 m included the Powerful Owl, Common Ringtail Possum and the Greater Glider. The Australian Owlet-nightjar, Common Brushtail Possum and possibly also the Tawny Frogmouth were widespread throughout the region avoiding only sites at high (>1 150 m) elevations. The Sugar Glider was also widespread, possibly avoiding only sites at low (<650 m) elevations. Sites at which no arboreal marsupials were recorded were more likely to occur at elevations greater than 1 150 m above sea level (Table 4).

Pattern in relation to broad vegetation type

Forest type appeared to be a major determinant of the distribution of nocturnal birds and arboreal marsupials (Table 5). All species were recorded either as expected statistically or most frequently in the Wet Peppermint forest type compared to other forest types. Other forest types were avoided by at least some species. Species apparently preferring the Wet Peppermint type included the Powerful Owl, Mountain Brushtail Possum, Greater Glider and the Yellow-bellied Glider. The Alpine Gums type was also preferred by the Mountain Brushtail Possum, Yellow-bellied Glider and by the Southern Boobook, but was apparently ignored by the Powerful Owl and the Greater Glider. No species appeared to prefer the Alpine Ash type compared to other types, and the Tawny Frogmouth and Common Ringtail Possum were not recorded in the Alpine Ash type. The Dry Peppermint type appeared to be favoured by the Australian Owlet-nightjar, Common Brushtail Possum and the Sugar Glider. The Western forest types were highly favoured by the Common Ringtail Possum and, less so, by the Common Brushtail Possum. The Mountain Brushtail Possum and

Table 4. Distribution by elevation class for nocturnal forest birds and arboreal marsupials on the southwestern slopes of New South Wales. Data represent the percentage of sites where each species was recorded. The total numbers of animals observed are also shown. Probability values are those resulting from test of association using contingency chi-square analyses of the raw data. n.s., not significant

Species	Elevation class (m above sea level) 300–649	650–899	900–1 149	1 150–1 450	Total number of sites	individuals	χ^2 value	*P*-value
Powerful Owl	10.9	13.7	5.6	1.5	19	19	7.77	= 0.05
Southern Boobook	23.4	23.5	46.5	47.8	92	119	15.15	< 0.01
Australian Owlet-nightjar	20.3	31.4	21.1	10.4	51	53	7.95	= 0.05
Tawny Frogmouth	9.4	7.8	8.5	3.0	18	18	2.46	n.s.
Mountain Brushtail Possum	1.6	5.9	25.4	16.4	33	44	19.90	< 0.01
Common Brushtail Possum	31.3	35.3	23.9	7.5	60	89	15.57	< 0.01
Common Ringtail Possum	18.8	19.6	2.8	1.5	25	38	20.35	< 0.01
Greater Glider	12.5	17.6	4.2	1.5	21	31	12.97	= 0.01
Yellow-bellied Glider	0.0	2.0	33.8	23.9	41	56	39.10	< 0.01
Sugar Glider	7.8	17.6	21.1	19.4	42	58	5.04	n.s.
No mammal species	43.8	37.3	25.4	53.7	101		12.15	< 0.01
No species	10.9	3.9	2.8	7.5	16		4.42	n.s.
Total number of sites	64	51	71	67	253			
% sites heavily logged	7.8	3.9	19.7	47.8	53			
% sites recently burnt	20.3	3.9	5.6	6.0	23			

Table 5. Distribution by broad forest type for nocturnal forest birds and arboreal marsupials on the southwestern slopes of New South Wales. Data represent the percentage of sites where each species was recorded. Probability values are those resulting from test of association using contingency chi-square analyses of the raw data. n.s., not significant

	Forest groups						
Species	Alpine Ash	Alpine Gums	Wet Peppermint	Dry Peppermint	Western Types	χ^2 value	*P*-value
Powerful Owl	4.5	0.0	13.3	13.8	3.9	10.8	< 0.05
Southern Boobook	36.4	54.3	37.3	31.0	21.6	11.6	< 0.05
Australian Owlet-nightjar	13.6	17.4	24.1	31.0	15.7	4.9	n.s.
Tawny Frogmouth	0.0	4.3	9.6	10.3	9.8	5.7	n.s.
Mountain Brushtail Possum	15.9	21.7	19.3	0.0	0.0	18.2	< 0.01
Common Brushtail Possum	2.3	21.7	27.7	34.5	31.4	15.5	< 0.01
Common Ringtail Possum	0.0	2.2	9.6	13.8	23.5	19.1	< 0.01
Greater Glider	4.5	0.0	15.7	10.3	5.9	11.4	< 0.05
Yellow-bellied Glider	13.6	39.1	20.5	0.0	0.0	34.6	< 0.01
Sugar Glider	15.9	23.9	16.9	31.0	2.0	14.1	= 0.01
No mammal species	56.8	32.6	31.3	31.0	51.0	12.38	< 0.05
No species	13.6	2.2	1.2	3.5	13.7	14.10	< 0.01
Total number of sites	44	46	83	29	51		
% sites heavily logged	70.5	15.2	14.5	0.0	5.9		
% sites recently burnt	9.1	4.4	3.6	20.7	15.7		

Yellow-bellied Glider were not recorded in the Western or Dry Peppermint forest types.

Patterns in relation to management history

Significant associations existed between logging intensity and elevation ($\chi^2 = 45.0$, d.f. = 6; $P < 0.01$), logging intensity and forest type ($\chi^2 = 90.0$, d.f. = 8; $P < 0.01$), occurrence of fire and elevation ($\chi^2 = 13.2$, d.f. = 3; $P < 0.01$), and occurrence of fire and forest type ($\chi^2 = 11.7$, d.f. = 4; $P < 0.05$). Far more heavily logged sites were surveyed at elevations above 900 m (33.3%), particularly above 1 150 m (47.8%), compared to elevations below 900 m (6.1%). Therefore, the forest types occurring at higher elevations were exposed to greater logging intensity: 70.5% of sites in Alpine Ash were heavily logged, compared to 15.2% in Alpine Gums, 14.5% in Wet Peppermints, 0% in Dry Peppermints and 5.9% in Western forest types (Table 5). The occurrence of fire appeared to be nearly inverse to that of logging. For example, 20.3% of sites at low (<650 m) elevations were recently (<5 years) burnt compared to 6.0% at high (>1 150 m) elevations. Similarly, 9.1% sites in Alpine Ash had been burnt compared to 17.5% sites in the Dry Peppermint and Western forest types.

The extent of these interactions between environmental variables limited assessments of the impact of management history on the fauna in the region. A consideration of the impact of past logging was undertaken by partitioning the data to include only those sites (n = 129) occurring in two of the three commercially logged forest types: the Alpine Gums and the Wet Peppermint types. These two broad forest types had similar proportions of heavily logged sites, 15.2% and 14.5%, respectively, and similar proportions of recently burnt sites, 4.4% and 3.6%, respectively (Table 5). Overall, logging appeared to have little influence on species detectability, but samples were inadequate for the Powerful Owl, Tawny Frogmouth, Greater Glider and the Common Ringtail Possum. Tests reached statistical significance for only two species. The Mountain Brushtail Possum was recorded more often in selectively logged forest than in unlogged or heavily logged forest ($\chi^2 = 9.43$, d.f. = 2; $P < 0.01$), and the Southern Boobook was recorded more often in selectively logged and heavily logged forest than in unlogged forest ($\chi^2 = 5.15$, d.f. = 2; $P < 0.1$).

Similarly, the relations between species and the numbers of retained hollow-bearing trees per ha were assessed only for the above subset of 129 sites. The distribution of sites in each habitat tree category was similar across the two broad forest types ($\chi^2 = 0.61$, d.f. = 2; n.s.) and the mean number of habitat trees was 2.4/ha (s.e. = 0.3) for the Alpine Gums forest group and 2.5/ha (s.e. = 0.2) for the Wet Peppermint forest group. Again, samples were inadequate for the Powerful Owl, Tawny Frogmouth, Greater Glider and the Common Ringtail Possum. Of the remaining species, tests reached statistical significance only for the Mountain Brushtail Possum which was recorded rarely when fewer than two habitat trees per ha were present ($\chi^2 = 4.63$, d.f. = 2; $P < 0.1$).

A consideration of the impact of forest fragmentation in the region was undertaken by partitioning the data to include only

those sites (n = 80) occurring in the two dry forest types: the Dry Peppermint and the Western types. The frequency of occurrence of species in these two forest types was then compared between the smaller, more isolated forests in the region (28 sites), which included Benambra, Carabost, Ellerslie, Livingstone, Minjary, Murraguldrie, Pulletop and Tumblong (not surveyed) State Forests (Fig. 2), and the larger, less isolated forests to the south and east (52 sites). Survey sites among the small, isolated forests sampled only the Dry Peppermint and Western forest types, which were probably the only forest types present, although the Western types were predominant (89% of sites). An even distribution of these two forest types was sampled among the larger forest areas. Mean elevations for survey sites were 488 m (s.e. = 22.2) among the small, isolated forests and 625 m (s.e. = 20.3) among the larger forest areas. Survey sites between the two fragmentation classes occurred across a similar range of geologies, but there was a greater incidence of logging and fire in the small, isolated forests.

The most significant result was that the likelihood of recording nil species at a site was three times greater in the small, isolated forest areas ($\chi^2 = 5.4$, d.f. = 1; $P < 0.05$). However, four species, including the Southern Boobook, the Australian Owlet-nightjar, the Common Brushtail Possum and the Common Ringtail Possum, occurred independently of the degree of forest fragmentation ($P > 0.1$). Samples were inadequate for the remaining species. The Yellow-bellied Glider and the Mountain Brushtail Possum did not occur in the Dry Peppermint and Western forest types and thus would not be expected to occur in the small forest isolates. The Powerful Owl and the Greater Glider, although present in these two forest types, appeared to be absent from the smaller forest isolates.

DISCUSSION

Species-habitat relationships

The major factors accounting for the distribution of nocturnal birds and arboreal marsupials in the Tumbarumba Hardwoods Region were correlated with a gradient in elevation. These factors included climate, geology, forest type, topography, logging and fire history. The biplot (Fig. 3) provided the clearest insights about species-habitat relationships in the region from the complex matrix of interacting variables. The two main variables operating independently of the elevation gradient that accounted for the distribution of species were the numbers of hollow-bearing trees per ha and the presence of the Wet Peppermint forest type. The distribution of the Greater Glider was best explained by these two variables.

Relatively few hollow-bearing trees per ha were present on survey sites throughout the region compared to other regions where similar counts have been made. This study found that 45.5% of sites had either 0 or 1 hollow tree per ha, and that all 253 sites averaged only 1.8 trees per ha that contained at least one large hollow suitable for nesting or shelter. These data contrast with 26.5% of 291 sites in northeastern New South Wales that had 0 or 1 hollow-bearing tree per ha (Kavanagh *et al.* 1995b) and 15.4% of 228 sites in southeastern New South Wales (Kavanagh and Peake 1993b). In similar but unlogged gum-peppermint forests at Waratah Creek (800 m elevation) on the eastern edge of the Great Dividing Range, a 100 ha study area averaged 22.8 trees per ha with hollows potentially suitable as glider den sites (Kavanagh 1987). Allowing for observer variability between these studies, the data suggest that a shortage of suitable nesting hollows may exist throughout much of the Tumbarumba Hardwoods Region.

The high elevation Alpine Ash forests were generally poor habitat for most species of arboreal marsupials and nocturnal birds (see also Bennett *et al.* 1991). The Yellow-bellied Glider, Mountain Brushtail Possum, Sugar Glider and Southern Boobook were the only species commonly recorded. These forests had been heavily logged compared to adjacent stands of the Alpine Gums forest type which generally contained higher abundances of species. Habitat quality for nocturnal birds and arboreal marsupials, as measured by frequency of occurrence, was greater in the Alpine Gums forest type than in Alpine Ash. The four species listed above were each recorded more frequently in the Alpine Gums forest type and two additional species, the Common Brushtail Possum and the Australian Owlet-nightjar, increased in abundance. However, the reasons for the paucity of records at high elevation, and particularly in Alpine Ash forests, were not clear. Unfortunately, few undisturbed stands of Alpine Ash were available for comparison. Two older-age Alpine Ash stands sampled in Kosciuszko National Park resulted in nil records for both sites. Large hollows do not appear to form in *E. delegatensis* until the trees are of a very large size. The low numbers of hollow-bearing trees in the Alpine Ash (mean = 1.6 trees per ha), most of which were dead "stags", may have limited the quality of habitat for animals. However,

greater numbers (mean = 2.4 trees per ha) of apparently suitable (live tree) hollows were available nearby in the Alpine Gums forest type.

A consideration of the nutritional differences between forest types, as indexed by the foliar nitrogen content of mature leaves (Braithwaite *et al.* 1983; Kavanagh and Lambert 1990), was also not illuminating. For example, the mean concentration of nitrogen (% of dry matter) in the mature leaves of 6–16 trees for each species sampled in Bago and Maragle State Forests was 1.60 for *E. delegatensis*, 1.54 for *E. camphora*, 1.44 for *E. stellulata*, 1.31 for *E. pauciflora*, 1.17 for *E. dalrympleana*, 1.17 for *E. bridgesiana*, 1.05 for *E. mannifera*, 1.03 for *E. globulus* and 0.94 for *E. macrorhyncha* (Lambert and Turner, pers. comm.). Unfortunately, the two peppermint eucalypts (*E. robertsonii* and *E. dives*) were not sampled, but these species are expected to contain relatively high concentrations of foliar nitrogen (Braithwaite *et al.* 1983; Kavanagh and Lambert 1990). The foliage nutrient data suggest that the Greater Glider was expected to be more common in both the Alpine Ash and the Alpine Gums forest types.

A partial explanation for the generally low fauna abundance in the higher elevation forests of the region is the cold, wet climate above 1 200 m where regular heavy snowfalls are encountered. Mean minimum temperatures are 4°C or less for seven months of the year at the Pilot Hill meteorological station (1 100 m) in Bago State Forest. Mean annual rainfall exceeds 1 400 mm (Anon. 1984).

The best habitats for arboreal marsupials and nocturnal birds, as measured by species richness and abundance, were provided by the Wet Peppermint and the Dry Peppermint forest types. Most species were recorded in one or both of these two forest types which occurred predominantly at mid-elevations (700–1 000 m; Fig. 4). A similar result was obtained for these forest types east of the Great Dividing Range in southeastern New South Wales (Braithwaite 1983) and across the border in northeastern Victoria (Bennett *et al.* 1991). The peppermint forest types have been deliberately selected in the past for clearing to establish pine plantations (Braithwaite 1983; Anon. 1984).

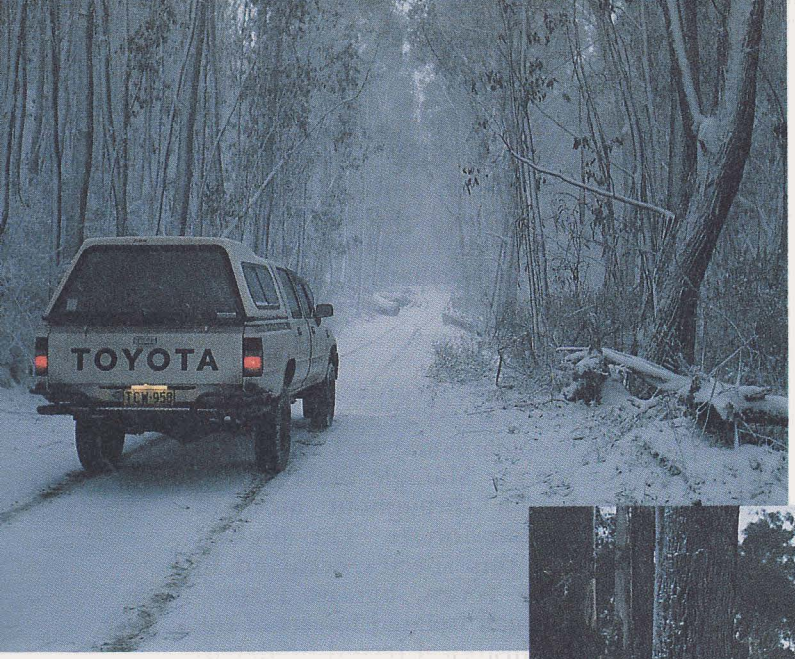
The low elevation Western (box, stringybark) forest types were the stronghold of the Common Ringtail Possum, but the Common Brushtail Possum and Tawny Frogmouth were also common. The data suggested that all three species may be adaptable to disturbance caused by fire and habitat fragmentation. Bennett *et al.* (1991) also reported the Common Ringtail Possum and the Common Brushtail Possum to be most abundant in northeastern Victoria at lower elevations in mixed box and red stringybark forests.

Species accounts

The Powerful Owl was recorded in all four of the large state forests (Bago, Maragle, Buccleuch and Woomargama) and in Clarkes Hill State Forest near Maragle State Forest, but was uncommon throughout most of the higher elevation forests. The highest detection rate for this species occurred in Woomargama State Forest, but no records were made in the small isolated forests of the region (Fig. 2). An historical record (undated) exists for Livingstone State Forest (Debus and Chafer 1994) but no records were made in that area during this survey.

The Masked Owl, Sooty Owl and Barking Owl were unrecorded during this survey despite the use of appropriate sampling techniques. The high frequency of records (16.9% of sites over two counts) of the Sooty Owl in Mountain Ash *E. regnans* forests of the Central Highlands in Victoria (Milledge *et al.* 1991) compared to nil occurrences in this study suggests that Alpine Ash may be unsuitable habitat for this species. Furthermore, the paucity of rainforest, compared to the Mountain Ash forests, suggests that Sooty Owls may not occur in the region. Both the Masked Owl and Barking Owl probably occur in the region but at very low abundance. Both species have been recorded in Bungongo State Forest (Table 3). Remnant riparian forests in the region may include most of the remaining habitat for the Barking Owl (Kavanagh *et al.* 1995a).

The Southern Boobook and the Australian Owlet-nightjar were commonly recorded species that probably occur in all forested parts of the region. Both species remained undetected in six of the smaller State Forests but this may have been due to limited sampling in these areas which also occurred outside of the breeding season for these birds. The White-throated Nightjar was recorded at only one site, but autumn sampling was not adequate for this summer breeding winter migrant. White-throated Nightjars were seen in other parts of the region while driving between sites but, during surveys, only one was heard calling. The Spotted Nightjar was recorded only in the western part of the region. The Tawny Frogmouth was recorded in low numbers throughout the region although they appeared to be uncommon in Bago State Forest.



▷

Recent logging among the intensively managed Alpine Ash stands in Bago State Forest. Snow in the foreground.

Photography by M. Stanton.

◁

Forest cover is mainly restricted to hilly areas in the western part of the region, while the valleys are usually cleared for agriculture. Woomargama State Forest.

Photography by M. Stanton.

▷

Dry open forest and woodland are the vegetation types among the small forest isolates in the western part of the region. Livingstone State Forest.

Photography by M. Stanton.

The Greater Glider is reported by other studies (e.g., Kavanagh and Bamkin 1995; Kavanagh *et al.* 1995b) to be most abundant in forests occurring at high (>700 m) elevations. The present study found the Greater Glider to avoid the highest elevation forests sampled and to occupy more of the lower elevation forests than expected. This species was most frequently recorded in Woomargama State Forest, however, only two records of the Greater Glider were made throughout Bago and Maragle State Forests, and several others from northern Buccleuch, Green Hills, Munderoo and Bungongo State Forests. The restricted distribution of the Greater Glider and the relatively few records made during this study contrast markedly with the reported abundance of this species in Buccleuch State Forest in the 1960s in forests felled to establish pine plantations (Tyndale-Biscoe and Smith 1969a, 1969b). Also, the Greater Glider was the second most abundant species reported by Bennett *et al.* (1991) in northeastern Victoria.

Conversely, the Yellow-bellied Glider which is most abundant at lower elevations in both northeastern and southeastern New South Wales (Kavanagh and Bamkin 1995; Kavanagh *et al.* 1995b), was recorded only at higher elevations in the Tumbarumba region. A similar result was reported by Bennett *et al.* (1991) in northeastern Victoria. This species was commonly detected in both Bago and Maragle State Forests and less commonly in Buccleuch and Bungongo State Forests.

The Sugar Glider was commonly recorded in all but the Western forest types at low elevations. It is possible that this species has been "displaced" in these environments by its larger congener, the Squirrel Glider. Bennett *et al.* (1991) found the Squirrel Glider to occur exclusively in the drier forests below 300 m elevation, the lower limit for sites sampled in this study, and this may explain the paucity of records (one individual in Livingstone State Forest).

The Feathertail Glider, Eastern Pygmy Possum and the Koala were each recorded in Dry Peppermint forest. The tiny Feathertail Glider is difficult to detect by any means but it may be moderately common in the region as it also occurs commonly in the wetter forest types in southeastern New South Wales (Braithwaite 1983; Goldingay and Kavanagh 1995). The status of the Eastern Pygmy Possum in the region is unknown because this species is very difficult to detect by spotlighting and it may prefer *Banksia*-dominated communities for habitat. The single record of a Koala contrasts markedly with the abundance of this species in northeastern Victoria (Bennett *et al.* 1991) where it occupied wet and dry peppermint, and some western forest types.

The Common Ringtail Possum appeared to be locally abundant in forests below 900 m elevation. This species was common in wet and dry peppermint and the Western forest types. Similar results were obtained by Bennett *et al.* (1991). Common Ringtail Possums also occurred throughout the small, isolated forests in the western half of the region.

The Mountain Brushtail Possum was recorded in most higher elevation areas of Bago, Maragle and Buccleuch State Forests, as well as in Green Hills and Munderoo State Forests, the latter possibly being the most westerly record of occurrence for this species in New South Wales. Bennett *et al.* (1991) also found this species to be restricted to the wetter forests at higher elevations. Before this survey, the Mountain Brushtail Possum had apparently not been recorded in the region except for a single specimen from Buccleuch State Forest. Most animals observed were of the grey morph and looked similar to the Common Brushtail Possum, but could be recognized by characteristics of the ears and markings on the face, and by their different vocalizations. The Mountain Brushtail Possum is reportedly of the dark colour morph in the eastern watersheds of Kosciuszko National Park (Anon. 1946), but we have commonly encountered the grey morph in the coastal ranges of southeastern New South Wales.

The Common Brushtail Possum was the most abundant arboreal marsupial in the region, a finding similar to that of Bennett *et al.* (1991) across the State border. This species was most commonly recorded at lower elevations among the Dry Peppermint and Western forest types, but it was also recorded at 1 260 m among Alpine Ash. Despite this wide distribution, the Common Brushtail Possum displayed little overlap with the wetter forest inhabiting Mountain Brushtail Possum. The two species were recorded at the same sites on only four occasions.

Conservation significance of the region

Similar studies of both nocturnal birds and arboreal marsupials have been undertaken in northeastern and southeastern New South Wales (Kavanagh and Peake 1993b; Kavanagh and Bamkin 1995; Kavanagh *et al.* 1995b), and on the Central Highlands of Victoria (Milledge *et al.* 1991). Two additional surveys sampled regional populations of arboreal marsupials in southeastern New South

Wales (Lunney 1987) and in northeastern Victoria (Bennett *et al.* 1991). The survey by Kavanagh and Bamkin (1995) was most comparable to the present study because identical methods were used, including only one count per site and in the same season of the year (autumn). However, the following comparisons need to be treated with caution as there may be other sampling bias associated with each study.

The abundance of nocturnal birds and arboreal marsupials in the Tumbarumba Hardwoods Region was low or patchy compared to other regions (Tables 6a and 6b). Species poorly represented included the Powerful Owl, Australian Owlet-nightjar, Greater Glider, Yellow-bellied Glider and the Sugar Glider. The Masked Owl and the Sooty Owl appeared to be absent, although a recent (1996) record may refer to the Masked Owl. Numbers of the Koala, Common Ringtail Possum and the Greater Glider were lower than expected compared to a similar, adjacent region in northeastern Victoria. In contrast, numbers of the Mountain Brushtail Possum, Yellow-bellied Glider and the Sugar Glider were much higher on the South Western Slopes of New South Wales than in north-eastern Victoria. Indeed, the Mountain Brushtail Possum appeared to be more abundant only in one other region, the Central Highlands of Victoria. The Common Brushtail Possum was recorded at a similar frequency of occurrence to northeastern Victoria where this species was more abundant than in other regions. The Feathertail Glider and the Eastern Pygmy Possum were not surveyed adequately in any study for comparisons. Species that remain poorly known and which are likely to be significant in the region include the Barking Owl, Masked Owl, Koala and the Squirrel Glider. The Brush-tailed Phascogale *Phascogale tapoatafa* has been recorded among the Western forest types in northeastern Victoria (Bennett *et al.* 1991; Traill 1991) and it is likely to occur in the present study area. Anecdotal reports suggest that numbers of the Tiger Quoll *Dasyurus maculatus* have suffered a marked decline in the region

Table 6a. Relative abundance of nocturnal forest birds and mammals in four regions of southeastern Australia. Data represent the frequency of occurrence (% of sites) for each species as determined by listening, call playback and spotlighting surveys.

Region/Study Sample Size (No. Sites) Season Species	SWSNSW n = 253 Autumn	SENSW[1] n = 200 Autumn	SENSW[2] n = 228 Win/Spr/Sum	NENSW n = 291 Win/Spr/Sum	CVH n = 130 Aut/Win/Spr
Powerful Owl	7.5	17.5	9.7	38.8	3.9
Southern Boobook	36.4	37.0	67.1	75.6	12.3
Barking Owl	0	*0	*0	*1.7	*0
Sooty Owl	0	8.0	4.4	20.6	16.9
Masked Owl	0	5.0	3.5	11.3	0
Australian Owlet-nightjar	20.2	52.0	46.9	54.3	2.3
White-throated Nightjar	0.4	4.5	16.2	7.2	0
Tawny Frogmouth	7.1	6.0	2.6	15.8	0.8
Koala	0.4	2.0	0.4	11.7	0
Mountain Brushtail Possum	13.0	7.5	4.8	11.0	18.9
Common Brushtail Possum	23.7	6.5	8.3	11.7	0
Common Ringtail Possum	9.9	9.0	19.3	14.4	0
Greater Glider	8.3	19.5	18.9	51.2	36.9
Yellow-bellied Glider	16.2	28.5	38.2	26.8	27.7
Squirrel Glider	T0	0	0	1.0	0
Sugar Glider	16.6	45.0	38.6	39.5	3.9
Eastern Pygmy-possum	0.4	0	0.4	0	0
Feathertail Glider	0.4	0.5	3.1	1.7	0.8

Data Sources:

SWSNSW This survey.

SENSW[1] Kavanagh and Bamkin (1995), southeastern New South Wales. Same methods used as this survey.

SENSW[2] Kavanagh and Peake (1993b), southeastern New South Wales. Similar methods used as this survey, except that sampling occurred in different seasons, each site was sampled twice, a 1 hour listening period was used, and less powerful speakers were used to broadcast owl calls.

NENSW Kavanagh, Debus, Tweedie and Webster (1995b), northeastern New South Wales. Similar methods used as in this survey, except that sampling occurred in different seasons, each site was sampled twice, and a 1 hour listening period was used.

CVH Milledge, Palmer and Nelson (1991), Central Victorian Highlands. Similar methods used as this survey, except that sampling occurred in different seasons, each site was sampled twice, and a 5 minutes listening period was used.

* Not specifically targetted for survey.

Table 6b. Relative abundance of arboreal marsupials in three regions of southeastern Australia. Data represent the frequency of occurrence (% of total records) for each species as determined by spotlight surveys.

Region/Study Sample Size (No. Animals) Season Species	SWSNSW n = 320 Autumn	SENSW[3] n = 347 All seasons	NEVic n = 995 All seasons
Koala	0.3%	0%	5.2%
Mountain Brushtail Possum	13.8%	0%	5.9%
Common Brushtail Possum	27.8%	7.5%	29.5%
Common Ringtail Possum	11.9%	6.6%	18.9%
Greater Glider	9.7%	13.0%	32.7%
Yellow-bellied Glider	17.5%	22.5%	1.3%
Squirrel Glider	T0%	0%	1.0%
Sugar Glider	18.1%	47.8%	4.2%
Eastern Pygmy-possum	0.3%	0%	0%
Feathertail Glider	0.6%	2.6%	1.3%

Data Sources:

SWSNSW This survey.

SENSW[3] Lunney (1987), southeastern New South Wales. Primary method included spotlighting from a moving vehicle and on foot.

NEVic Bennett, Lumsden, Alexander, Duncan, Johnson, Robertson and Silveira (1991), northeastern Victoria. Primary method included spotlighting on foot.

T Detected by supplementary targetted surveys.

(B. Gall, pers. comm.) and no records were made during this survey.

The conservation significance of the region may be improved in several ways. Further decline in the extent and condition of the Wet Peppermint forest type needs to be addressed. The habitat for the Greater Glider in particular has been reduced greatly by clearing of this forest type for agriculture and plantation establishment. The degree of forest isolation and fragmentation of the landscape should be reduced. In particular, samples of the predominantly privately-owned forests at lower elevations on flat land and in riparian zones need to be reserved or restored for nature conservation. A general increase in the numbers of hollow-bearing trees throughout many forest areas would benefit most species of nocturnal birds and arboreal marsupials (Meredith 1984; Traill 1991). A reduction in fire frequency in selected low elevation forests may also be beneficial to fauna.

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